ABRASIVE TESTING CABINETS
A STATE OFT HEAR TSTUDY

June 1985

U.S. DEPARTMENT OF TRANSPORTATION

MARITIME ADMINISTRATION

IN COOPERATION WITH

AVONDALE SHIPYARDS; NEW ORLEANS, LOUISIANA

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FOREWORD

This research project was performed under the National Shipbuilding Research Program. The project, as a part of this program, is a cooperative cost shared effort between the maritime Administration and Avondale Shipyards, Inc. The development work was accomplished by Associated Coatings Consultants under subcontract to Avondale Shipyards, Inc. The overall objective of the program is improved productivity and, therefore, reduced shipbuilding costs.

The studies have been undertaken with this goal in mind, and have followed closely the project outline approved by the Society of Naval Architects and Marine Engineers' (SNAME) Ship Production Committee.

Mr. Walter H. Radut of W.H. Radut Associates in Bricktown, NJ served as principal investigator. Mr. John Peart of Avondale Shipyards was the R&D Program Manager responsible for technical direction and publication of the final report. Program definition and guidance was provided by the members of the 023-1 Surface Preparation and Coatings Committee of SNAME.

Appreciation is expressed to those who contributed information to this report. Please reference acknowledgements for those people and organizations.

SUMMARY

Eight test cabinets are reviewed and details are in the Appendix. There are many variables in the equipment and the way the tests were run. No one cabinet simulates open blasting as produced in the field. However, it is recommended that research be conducted to determine if a correlation can be made between the cabinet tests and actual field applications.

It is proposed in this report that the research be conducted in three phases:

<u>PHASE I</u> -- Appoint a Task Group
Develop parameters for'the tests

<u>PHASE II</u> -- Conduct tests in three cabinets
Compare the results

<u>PHASE III</u>-- Conduct field tests and determine if they can be correlated with the cabinet tests; if so, then develop a standard cabinet test

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PURPOSE

The purpose of this mini-study was to investigate the tabilityof existing abrasive test cabinets to be used as standard equipment for evaluating abrasives. These are abrasives used to prepare steel surfaces for coating.

This work is to be presented to S.N.A.M.E. Panel 023-1 for their consideration for further research into developing an abrasive test standard.

INTRODUCTION

There is considerable work being done on developing specifications and/or guide-lines for abrasives. SSPC, ASTM, NAVSEA, NACE and others are involved in this work. Most of the physical testing and chemical testing is standardized either by ASTM methods or by using proprietary equipment. There are some performance characteristics, however, which are important to the evaluation of abrasive mate-rials for which there are no standard tests. Examples are cutting rate, friability, and dust generation. Various investigators have constructed test chambers or test cabinets to conduct such tests.

At the last meeting of S.N.A.M.E. Panel 023-1 in New Orleans, LA the Chairman, John Peart, suggested that the panel consider taking on a project to develop a “standard” test for those factors which are being investigated but for which no standards exist. It was proposed that a research project sponsored by the panel be initiated to develop a test cabinet and a method of conducting these tests.

While the panel was receptive and recognized the need for standards in this work, it was decided that an investigation into what existing equipment is avail-able should be done before designing something brand new. As a result, the panel voted to conduct a mini-study to investigate the current state of the art and to report the findings at the next panel meeting. This is that report.

BACKGROUND

The investigation revealed that considerable work has been done on the subject of test cabinets. Eight projects were found for which test cabinets were constructed. These projects are described briefly as follows:

Long Beach Naval Shipyard - 1963

This was one of the first attempts to compare abrasives for performance versus cost as concerns blasting of ship bottoms on drydock.

N.A.C.E. - 1964

From 1962 - 1964 NACE Task Group T-6G built a cabinet to develop a standard test, but there were criticisms that were never fully resolved and it was not adopted as a standard.

DUPONT- 1964

The NACE cabinet was not adaptable to DUPONT’S staurolite material so they developed a cabinet of their own.

CALIFORNIA D.O.T. - 1975

At this time pollution reared its ugly head. The California Air Resources Board developed a cabinet which is used today by the California Transportation Department to approve all abrasives purchased for highways and bridges in California. This is also the cabinet described in the current MIL Spec.-A - 22262.

BETHLEHEM STEEL - 1976

This user of abrasives conducted tests to evaluate the performance of various abrasives used in their shipyards. They built a simple test apparatus to perform the work. As a result of these tests, a chapter on abrasives was written in Volume 1 of the current Steel Structures Paintina Manual.

HUGHES AIRCRAFT- 1978

This company conducted a comprehensive study for Long Beach Naval Shipyard and they used a setup similar to BETHLEHEM STEEL'S. This equitpment was for comparison testing and they added a test for dust plume.

OCEAN CITY RESEARCH - 1984

This was a project sponsored by SNAME 023-1 in which the principal objectives were to catalog sources of mineral slag abrasives for U.S. Shipyards and to develop a tentative material specification for such abrasives. They built a small laboratory size test apparatus especially for this test.

ROCKY MOUNTAIN ENERGY - 1984

This abrasive supplier developed a test cabinet to do competitive testing. They purchased samples of low silica mineral abrasive from the marketplace and tested it on their cabinet which was also built especially for this purpose.

Not all of these cabinetmakers had the same objective and there was no incentive to standardize. They were individual tests.

There is no doubt that there is similar equipment in other establishments. It is felt, however, that the. above gives a broad brush review of what has been used until now.

DESCRIPTION OF ABRASIVE TEST CABINETS

A review of how each of the test cabinets operates is discussed in the following paragraphs. Some of the differences in procedures and methodology will be highlighted. Various details-are included in the Appendix.

Table 1 provides a listing of components, scope, and objectives of each of the eight cabinets for comparison. (See Page 19).

1. Long Beach Naval Shipyard - 1963

This test equipment is on a larger scale than the others. It was set up in a 20′ x 60′ Pangborn, Building. Only cutting rate is determined in this test. The equipment consists of a powered monorail which moves the equipment horizontally and a vertical traveling nozzle carriage which moves the nozzle up and down at a controlled rate. The nozzle is ½-inch size positioned on the vertical traveling carriage a distance of 18 inches from the test panel. The nozzle moves up and down at a rate of 17.5 ft/min. It was proven that a 90-degree angle of incidence resulted in the most rapid cutting rate.

The test panels used in this work are Poly Vinyl Chloride and are 8″ wide, 4′ long and ¼" thick. The purpose of this plastic medium was to simulate vinyl paint films on ship bottoms. The test panel is weighed in grams, attached to a steel backup plate, and blasted 150 seconds with approximately 36 pounds of abrasive. The panel is then reweighed and the loss reported as pounds of PVC removed per hour. (Ultimately the cutting rate is reported as Grams PVC per Pound of Abrasive).

The quantity of abrasive material used is sufficient to run one test. It is accurately weighed and fed into a blasting machine and delivered at 100 psl through a ½-inch orifice into 50 feet of I½-inch hose to the nozzle. The remaining sand in the blasting machine is weighed and the consumption of abrasive is calculated as tons of abrasive used per hour.

Three tests were run with the same abrasive material on three (3) test panels and the results were averaged.

Sieve analysis was done before testing but not after blasting. The cabinet was too large to collect the spent abrasive.

Atypical test result is shown in Appendix A-1.

Although this method was recommended as a standard by the U.S. Navy in conjunction with MIL-A-22262, it obviously was not the answer for many of the investigators at that time. The use of PVC panels, for example, did not address the cutting of steel to near-white metal.

No photographs were reproducible from the photocopied report but details can be obtained from original copies of the report, “Abrasive Blasting Study”, Long Beach Naval Shipyard, October 9, 1963, by C.L. Shaw, Code 385.

2. National Association of Corrosion Engineers - 1964

This work was performed by NACE Technical Committee T-6G on Surface Preparation for Protective Coating. It was prepared by Task Group T-6G-1 on Abrasive Blast Cleaning Media for Surface Preparation, assisted by Task Group T-6D-13 on Surface Preparation Media.

The NACE CAB Testing Device was the first attempt to build a standard test cabinet. CAB is an acronym for Cabinet for Abrasive Breakdown and Abrading. This testing device is a rectangular-shaped metal cabinet which is one foot square by three feet tall with a converging lower hopper-type, 4-inch square outlet. It also has a 3-inch outlet which is connected to a dust collector. A photograph of this cabinet is shown in Figure 1.

Steel coupons, 3" x 4" x 3/16", can be mounted inside the cabinet at 45 degrees and 90 degrees. The abrasive sample is screened through a 20-mesh screen and retained on a 30-mesh. The theory is that this is the most common size abrasive and that to compare one material against another the same size material should be tested.

The 30-mesh is then measured in an 1/8 cu. ft. container (about 23 lbs.) for the test. This amount is blasted through a nozzle to the test coupon until all the sample is expended. This is the only test in which volume of abrasive is used rather than weight. The investigators felt that different specific gravity materials were compensated for by controlling the volume through the nozzle rather than the weight.

The test coupon was not weighed but it was measured before and after by a Micrometer to achieve depth of cut, reported in Mils. All other testers weighed the panel to measure cutting rate by weight loss.

No screen analysis was done, only screening through a 30-mesh screen, and the breakdown was measured as the percent of abrasive passing through the screen after blasting.

The following terminology was developed:

For cutting rate:	CAB Abrading No. - Mils
For friability:	CAB Breakdown - % of sample.
For profile:	CAB Breakdown Etch -Mils
For hardness:	CAB Hardness - % Retained After Blasting

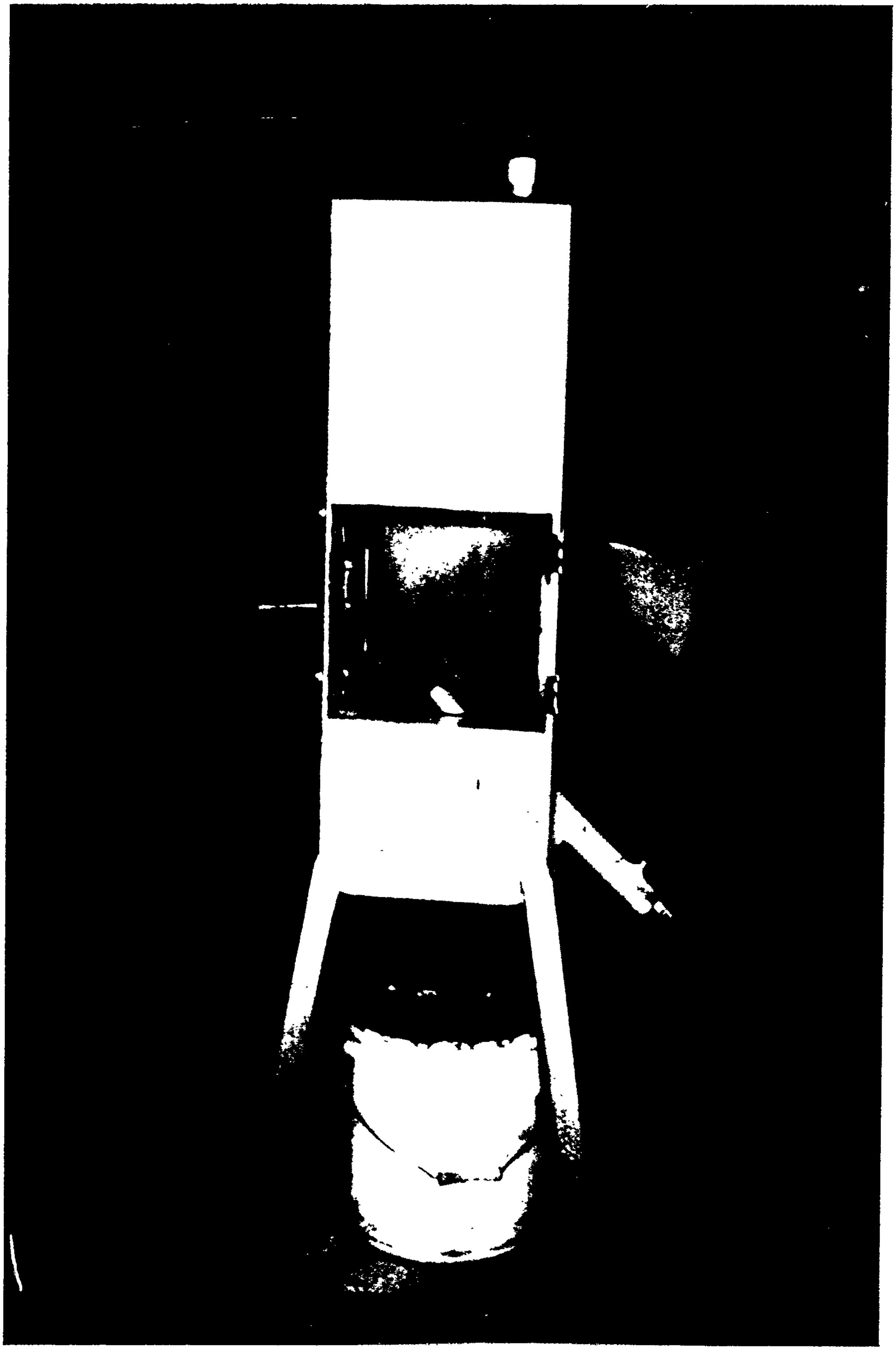
A description of the cabinet and the procedures as published in "Materials Protection" in July 1964 is shown in Appendix B-1.

It was estimated that the complete rig-including blasting pot and compressor was $8,000 and the cost per analysis today would be about $650 per sample. A 50-lb sample is required.

3. E. I. DuPont De Nemours & Co. - 1964

An abrasive breakdown cabinet was constructed of 16 gauge steel, approximately 10 inches wide and 18 inches long, standing on legs which makes it 30 inches high. A 3-inch square port on the side accommodates a blast nozzle whose tip is 14 inches from a steel target plate which is 8" x 8" x 1" thick. The lid of the cabinet is made up of 200-mesh screening.

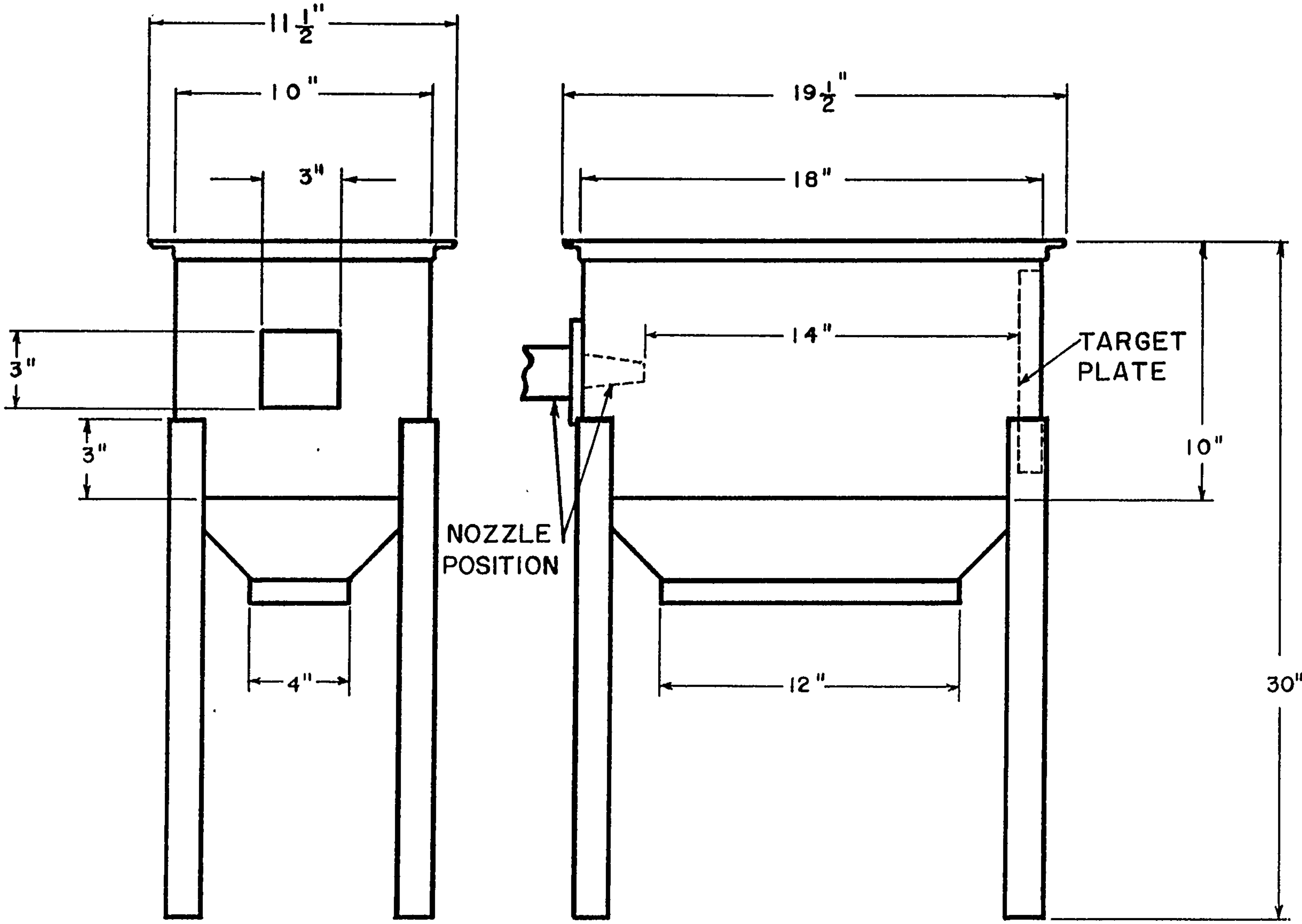
A sketch of this cabinet is Figure 2.



NATIONAL ASSOCIATION OF CORROSION ENGINEERS
CAB TESTING DEVICE

Figure 1

DU PONT— ABRASIVE BREAKDOWN CABINET



MATERIAL:

TANK— 16 GAUGE STEEL
LEGS— 1 1/4" X 1 1/4" X 1/8" ANGLE STEEL
TARGET PLATE – 8" X 8" X 1" STEEL
ALL WELDED CONSTRUCTION EXCEPT TARGET PLATE

Figure 2

A sieve analysis is run on a representative sample containing 200 grams of the test abrasive and the data recorded.

Ten pounds of abrasive are introduced into the blaster through a nozzle at 95 psi. All 10 pounds are expelled into the cabinet with the flow valve adjusted to give free, unchoked abrasive flow.

Abrasive and dust remain in the cabinet after blasting,is collected and weighed. A 200-gram sample-is taken for sieve analysis and a breakdown rating is calculated.based on the as received analysis. An adjustment is made for any fines that escaped through the 200-mesh lid.

The procedure for Abrasive Breakdown and the adjustment formula for loss of 200-mesh fines is shown in Appendix, Pages C-1 and 2.

This cabinet was constructed to test abrasives which are 70 - 100 mesh in size. The NACE cabinet described previously **used** only 20- 30 mesh size particles.

4. California Dept. of Transportation - 1975

An abrasive blasting unit was designed and fabricated by CALTRANS in cooperation with the committee on Air Pollution Standards for Abrasive Blasting Operations appointed by the California State Legislature and reporting to the California State Air Resources Board.

The test cabinetis a double chamber unit which is 8′ x 8′ overall and 8′ high. The air passes through an air cooler to knock out moisture and there are built-in vibrators to facilitate the removal of spent abrasive and dust.

A photograph of this unit is Figure 3.

The test procedure known as Test Method No. Calif. 371-A is as follows: Samples weighing 18,750 grams (approximately 41 lbs) were shot until exhausted through a 3/8-inch venturi nozzle at 100 psi into the test chamber. The blast stream impacted against a replaceable flat, mild, steel plate located 23 inches from and at a 90-degree angle to the nozzle tip. The impingement plate was changed after each test and the plate weighed before and after to determine the grams of steel abraded.

The abrasive is collected at three locations, i.e. the initial chamber, the secondary chamber, and the dust bag. The abrasive is then analyzed by sieve analysis and by using ASTM D422-63, Particle Size Analysis of Soils. From hydrometer readings versus time, a grain size accumulation curve is made. Appendix Dl, 2 and 3 provides details regarding the data analysis including a table of the gradation and cutting rate.

The sole purpose of this test cabinet is to determine the breakdown of the abrasive as it relates to dusting or plume. Plume is the airborne particulate matter generated during the process of open blasting.

CALIFORNIA DEPT. OF TRANSPORTATION

ABRASIVE BLASTING CABINET

FIGURE 3

Any abrasive which has in excess of 1.8 percent by weight of particles sized 5 microns or smaller fails the test.

In addition to this test, a separate dust generation test to measure plume is conducted by open blasting.

.5. Bethlehem Steel Corp. - 1976

The test apparatus built by this user of abrasives is a 55-gallon drum fitted with a cone-shaped bottom to collect the spent abrasive and a dust bag to-collect airborne dust. A photograph of the unit is Figure 4.

A 10,000 gram (approximately 22 lbs) sample of abrasive is introduced into the blaster at 95 psi. Inside the .55-gallon drum is a replaceable test plate positioned at a 45-degree angle to the blast stream and about 10 inches - 12 inches from the nozzle tip. Placing the impact plate at a 45-degree angle prevents rebounding abrasive from colliding with the abrasive blast stream. The airborne dust exits behind the impact plate and collects in the dust bag. The sample which collects in the cone bottom is recovered, weighed and sized. The difference between the starting weight and the weight of material recovered from the cone bottom is the amount of dust or airborne fines generated. The fines collect in the dust bag and can also be analyzed.

The breakdown rate is calculated from the before and after sieve analyses as shown-in Appendix Page E-1. A factor of 1.0 indicates no reduction from original size and O is for large grains that are reduced to dust. Most quality mineral abrasives will-have the rating of approximately 0.6.

This is a simple unit which requires no drawings. Whenever the drum wears out, a new one is made.

All this unit is used for is to determine breakdown value.

6, Hughes Aircraft Co. - 1978

This contractor developed a test apparatus and conducted tests for Long Beach Naval Shipyard. They conducted a few tests on the California D.O.T. cabinet described earlier because it was available. However, they decided that an apparatus similar to the Bethlehem Steel unit was a better choice for the remainder of the work.

Unfortunately, the drawing of the test apparatus and a description was omitted from the copy of the report. However, the test procedure was included and is shown in Appendix F1 - F7.

The equipment is described briefly as a standard 55-gallon steel barrel as the chamber and features changeable impingement plates mounted at 45 degrees to the abrasive nozzle. The test consists of impinging a measured-amount (44 lbs) of abrasive against the steel test plate and-comparing the sieve analysis before and after impingement.

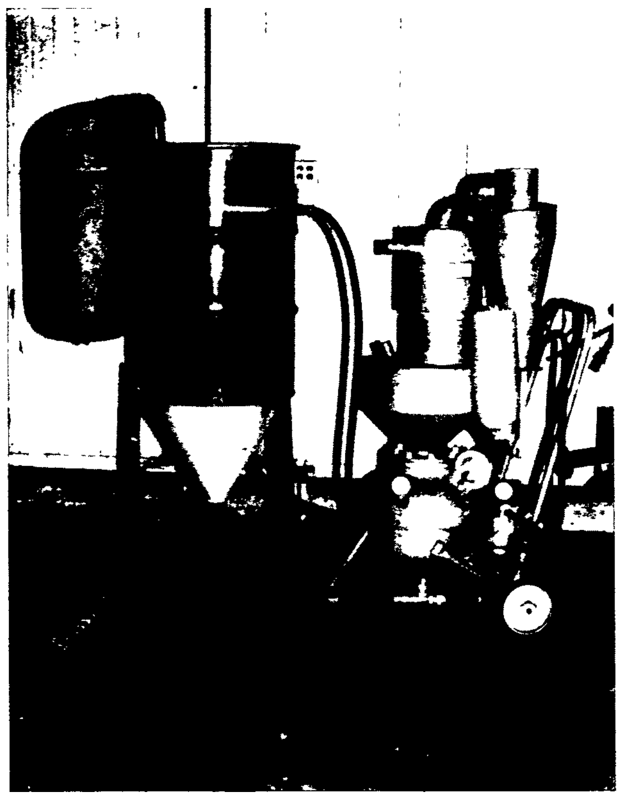


FIGURE 14. ABRASNE BREAKDOWN TEST EQUIPMENT

The portable blasting unit is on the right. The 55-gallon drum on the left has a cone shaped bottom to collect the spent abrasive. The dust bag attached to the drum collects the airborne dust.

HWH 9/76

FIGURE 4

In addition to the friability test, dust plume observations were made and the abrasive effects on surface conditions of the steel plate were evaluated.

7. Ocean City Research - 1984

A test chamber was constructed by this contractor to conduct tests of various abrasives for a project sponsored by SNAME Panel 023-1.

This was a laboratory size apparatus made from 12-inch diameter PVC pipe, 1/2-inch thick, and 4-feet long, flanged at both ends. The pipe is rubber lined to prevent wear and to keep the PVC from contaminating the abrasive. A funnel at the bottom catches the spent abrasive and a filter bag at the top collects the airborne fines. Figure 5 is a schematic of this apparatus.

A 3000-gram sample is introduced into the chamber at 90 psi. A ¼-inch nozzle is 7¼ inches from a steel test plate, 3″ x 5″ x ¼″, mounted at a 90-degree angle to the blast nozzle. The test plates, the filter bag and the catch bucket are weighed before and after blasting. A sieve analysis is also made before and after blasting.

The cutting rate is defined as the grams of metal lost from the test plate per kilogram of spent abrasive.

The breakdown rate is calculated similarly to the Bethlehem Steel method. The results are different because this unit is at a 90-degree angle of impingement whereas the Bethlehem Steel test plate was at a 45-degree angle.

The dust production is calculated as weight percent of dust generated.

Surface profile of the test plate is measured by three methods, i.e., Elcometer, Press-O-Film, and Surfanalyzer.

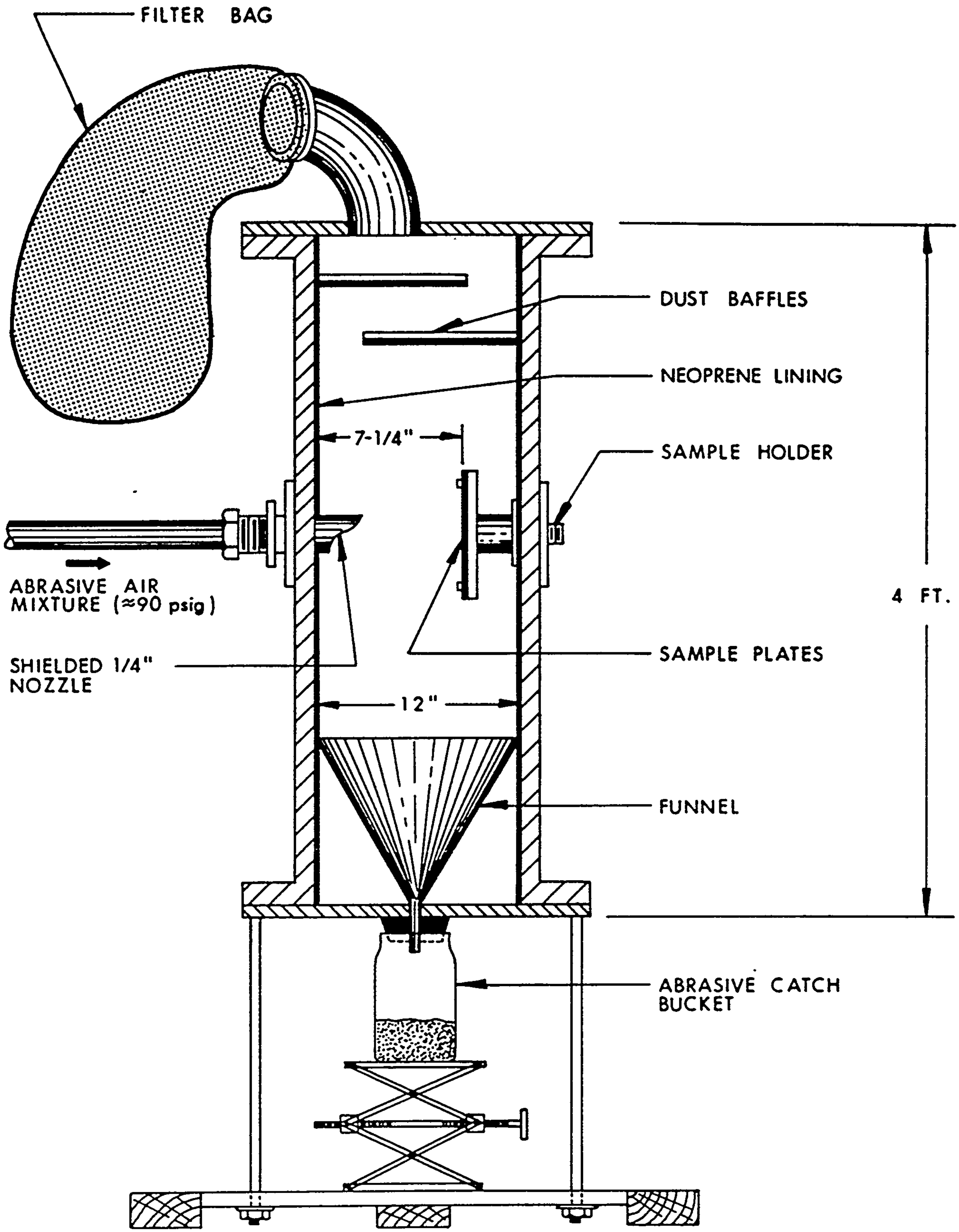
Appendix Pages Gl, 2 and 3 provides details concerning the various test procedures used to determine these factors.

8. Rocky Mountain Energy - 1984

This abrasive supplier constructed a test cabinet to compare their abrasives with competitors' products. They tested only low silica mineral abrasives. The unit is fabricated from 10-gauge steel. The chamber is 24 inches in diameter and 30 inches in height with a conical bottom extending down another 24 inches. The chamber stands on legs and is approximately 6 feet high overall.

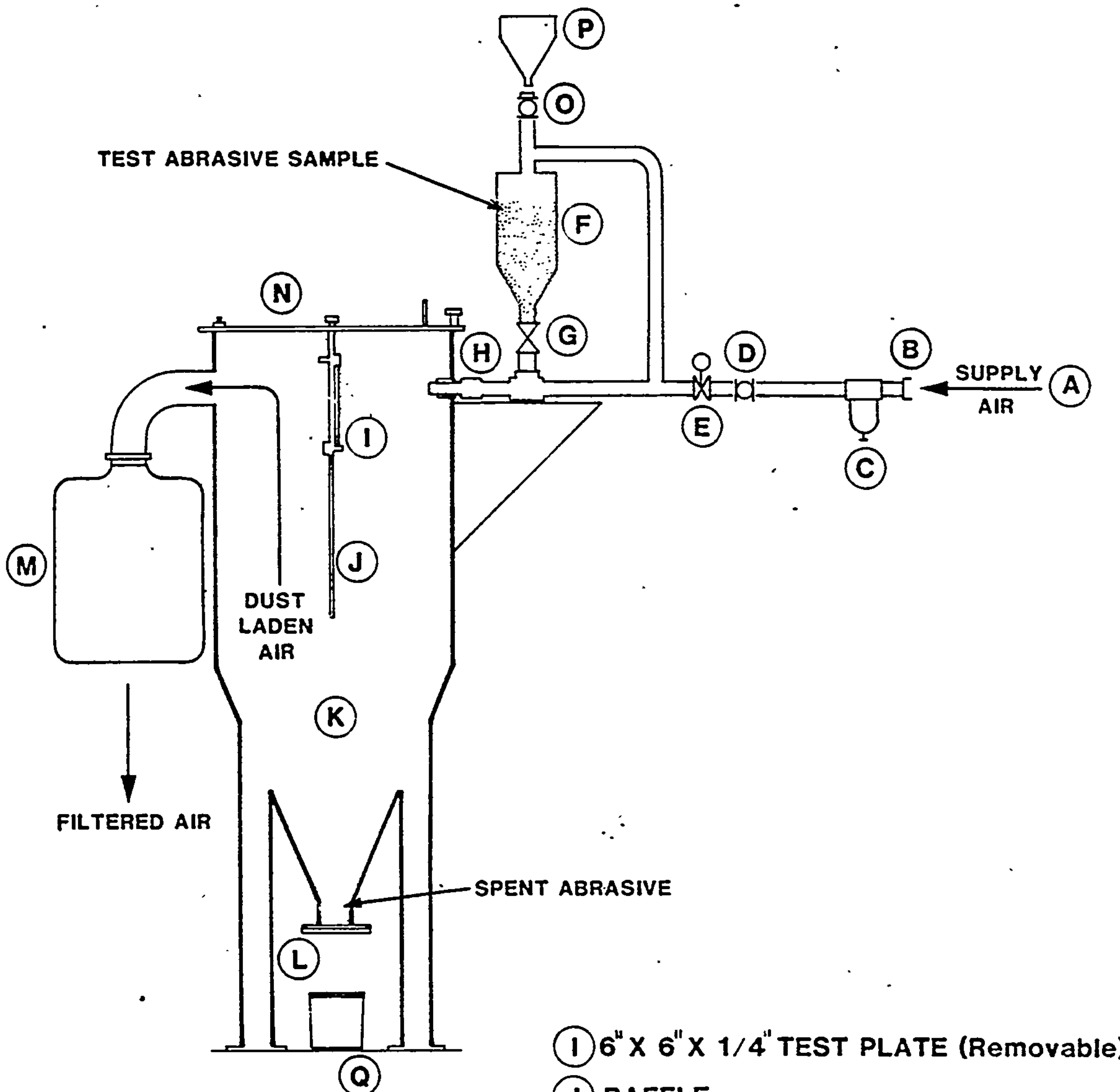
A diagram of this apparatus is shown in Figure 6.

There is a 6″ x 6″ x ¼″ plate mounted 90 degrees to a 3/8″ nozzle at the center of the chamber. Distance of the nozzle to the test plate is approximately 10 inches. A baffle plate is an extension-of the test plate



Abrasive Blasting Test Chamber

FIGURE 5



- (A) 375 CFM - 120 PSIG AIR SUPPLY
- (B) QUICK DISCONNECT COUPLING
- (C) MOISTURE SEPARATOR
- (D) BALL VALVE
- (E) PRESSURE REGULATOR
- (F) SAMPLE POT
- (G) SAND CONTROL METERING VALVE
- (H) 3/8" VENTURI NOZZLE
- (I) 6" X 6" X 1/4" TEST PLATE (Removable)
- (J) BAFFLE
- (K) 2' Dia. X 4'-6" CYLINDRICAL CHAMBER
- (L) SPENT ABRASIVE COLLECTION PORT
- (M) DUST COLLECTION BAG
- (N) ACCESS DOOR
- (O) BALL VALVE
- (P) ABRASIVE FUNNEL
- (Q) BUCKET

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FIGURE 6

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ROCKY MOUNTAIN ENERGY

SALT LAKE GRIT FACILITY

PILOT SCALE
BLASTING APPARATU!

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and is 24 inches long by 24 inches wide. Behind the plate is a 4-inch diameter opening with a filter bag attached. The spent abrasive is directed down into the conical bottom by the baffle plate and the dust laden air exhausts through the filter bag.

A 5000-gram (approx. 11 lbs) sample is blasted into the chamber at 80- 82 psi until exhausted.

The spent abrasive is collected at the bottom and the fines are collected in the filter bag. The test plate is weighed before and after and the plate is evaluated for cutting rate, imbedment and profile. The fines-in the bag were analyzed for trace heavy metals.

The spent abrasive in the bottom cone was not sieved but instead was rated merely as: Fine, Medium, Coarse.

A test procedure is shown in Appendix Pages H-1, 2, 3 and 4.

Duplicate tests were done on large areas of steel by open blasting and results did not correlate.

The cost to build this apparatus exclusive of air compressor is about $3,500. Cost to run the test is about $150 per sample. The accuracy and reproducibility has not been proven. However, if the many variables are controlled and as many factors kept constant as possible, reasonable data can be obtained. Many samples of many different types allowed a-statistical analysis to reach fairly accurate conclusions.

An engineering drawing is available for this cabinet.

OTHER TEST EQUIPMENT

The REED MINERALS DIVISION, an abrasive supplier, has a laboratory instrument which they use to test abrasives for friability. The test is described as follows:

The apparatus is approximately 8 inches high and consists of a ball approximately 3 inches in diameter which free falls between fixed guides to provide a 0.38 ft lbs impact in a steel dish at the bottom.

The sample is prepared by sieving the abrasive through a 10-mesh screen. Of the amount retained on the 10-mesh screen, 100 granules are selected at random and placed into the steel dish at the bottom of the apparatus. The ball is then dropped and the abrasive is crushed by the impact. The crushed abrasive is again sieved through the 10-mesh screen and the particles retained are counted. The breakdown ratio is the number of granules remaining divided by 100.

No drawing or written procedure could be obtained from REED.

Other investigators have tried similar type crush tests but” they report that crushing does not simulate fracturing by blasting. However, REED feels that this test gives a good Rank Order comparison of the different kinds of abrasives.

DISCUSSION

From the descriptions of the various abrasive test cabinets and the comparisons shown in Table 1, it is clear that no two apparatus are alike. Also, there are a number of variables in equipment from one cabinet to another which can greatly influence the results. The friability, dusting, cutting rate, imbedment, and profile are all dependent upon the force of impact of the particles against the surface being blasted. Although the hardness, shape, specific gravity and size of particle also determine surface configuration, variables in the blast stream contribute to nonuniformity between one test apparatus and another. These variables are discussed below:

VARIABLES:

Size of Chamber

The cabinets varied from 1 foot square for the NACE cabinet to 4 ft. x 8 ft. from the California D.O.T. unit.

Size of Feed Orifice

Most of the time this was not specified and where it was specified it varied depending upon the size of the nozzle. The orifice regulates the feed rate or size of abrasive stream through the nozzle. In MIL-A-22262 it is specified that for each abrasive tested, three samples are shot in the cabinet each at different feed rates. The requirement is that the initial orifice be selected to feed at a rate of 450 - 750 lbs/hr. Then the orifices are changed for the other two samples to provide approximately 15 - 25% overfeed and 15 - 25% underfeed.

Most other investigators prescribe the feed in terms of free, or unchoked flow. One instruction says, for example, that the flow is free if a bluish-white hue is visible when one looks through the path of air and abrasive as it comes from the nozzle. Another says the abrasive is metered so that it is on the lean side to insure maximum breakdown.

It is easy to see how variations from one abrasive to another or even with the same abrasive could vary test by test. The shooting of the three samples per test required by the MIL Specifications recognizes that no two abrasives are alike and that variations in feed rate have a great influence on impact to the steel test plate.

Size of Nozzle

This varied from 3/8-inch to 3/16-inch. At 90 psi the larger nozzle is capable of delivering 1000 cu. ft./rein. of sand whereas the smaller nozzle consumes no more than 250 cu. ft./rein. One is four times the other.

Nozzle Pressure

The nozzle pressure was 80, 90, 95 and 100 psi. Sometimes the pressure was not measured at the nozzle but upstream of the nozzle which means the true value is not known.

Size of Test Panel

This varied with the size of the nozzle and the distance from the nozzle. The largest was 13 ins. x 13 ins. which was for the Hughes Aircraft 55-gallon drum test. The smallest was 3 ins. x 4 ins. in the NACE cabinet. The larger area is fourteen times the smaller area.

Distance of Panel to Nozzle

This varied from 6 inches to 23 inches.

Weight of Abrasive Sample

Anywhere from 1500 grams to 20,000 grams of sample were used. These amounts impacted the respective test plates until. the supply was exhausted. One amount was 13 times the other.

Angle of Impingement

Most apparatus used a 90-degree angle of impingement but more than one used 45 degrees.

It is obvious that the results will vary from one apparatus to another with these wide variations. For any “standard” test all these factors will have to be addressed and the effects on the results weighed as to their importance.

PERFORMANCE CHARACTERISTICS:

In the introduction, examples were given of characteristics important to the evaluation of abrasives for which there are no standard tests. Figure 7 shows which of these characteristics were tested in the various cabinets. All but one test for FRIABILITY. Six of them tested for CUTTING RATE. Only three included DUSTING and PROFILE. Two tested for IMBEDMENT.

However, a number of the cabinets probably could be adapted for use in other categories, for example, Imbedment. About Cutting Rate and Profile there are comments later in this paper.

The units of measure also varied considerably from one cabinet to another. Figure 8 shows the various units of measure as designated for each test cabinet.

For the Friability tests those units which ’are not self-explanatory are explained as follows:

NACE - CAB Hardness - This is Breakdown % of sample expressed as 100 - the % of 30-mesh which passed through the 30-mesh sieve after breakdown.

DUPONT - Breakdown Rate - This is calculated from the formula:

the sum of the % Retained Spent Abrasive x average sieve opening

divided by

the sum of the % Retained as received Abrasive x average sieve opening

PERFORMANCE VALUES FROM TEST CABINETS

TEST CABINETS	FRIABILITY	DUSTING	CUTTING RATE	IMBEDMENT	PROFILE
LONG BEACH			X		
NACE	X		X		
DU PONT	X				
CAL. DOT	X		X		
BETH STEEL	X				
HUGHES AIR.	X	X	X	X	X
OCEAN CITY	X	X	X		X
ROCKY MTN.	X	X	X	X	X

FIGURE 7

VARIOUS TEST CABINETS VS. UNITS OF MEASURE

TEST CABINETS	FRIABILITY	CUTTING RATE
LONG BEACH	NONE	TONS ABRASIVE PER LB. PVC
NACE	CAB HARDNESS NUMBER	CAB ABRADING NUMBER – MILS
DU PONT	BREAKDOWN RATE	NONE
CAL. DOT	SIEVE GRADATION	GMS. STEEL ABRADED
BETH. STEEL	SAME AS DUPONT	NONE
HUGHES AIR	SAME AS DUPONT	WEIGHT LOSS GMS.
OCEAN CITY	SAME AS DUPONT	GMS. METAL / Kg. ABRASIVE
ROCKY MTN.	FINE, MEDIUM, COARSE	GMS. METAL / AVG. PARTICLE SIZE

FIGURE 8

CALIFORNIA D.O.T. - Sieve Gradation. This is the percent smaller after blasting calculated from the percent passing before blasting. See Appendix Page D-3.

For the Cutting Rate tests the units are self-explanatory except as follows:

NACE - CAB Abrading Numbers - Mils. This is the loss in Mils from original thickness to after abrasion thickness. The lower the abrading number the less productive is the abrasive; the highera the abrading number the more productive or the faster is the ability of the abrasive to remove metal.

It would appear that for Friability, the DuPont method is preferred by a number of investigators. However, although the calculations are similar, the test procedure for impacting the abrasive varied considerably. By this method a factor of 1.0 indicates no reduction from original size after blasting. A factor of zero means the particles break down completely to dust.

In the Ocean City Research tests the factor was 0.29 for the most friable of the coal slags and 0.45 for nickel slag and the toughest of the copper slags. This was using a 90-degree impingement angle.

In the Bethlehem Steel tests the factor was 0.60 for the good quality mineral abrasives but these were run at a 45-degree angle.

Concerning Cutting Rate there are almost as many ways of testing and units. of measure as there are investigators.

For Dusting determinations only three of-the eight test cabinets measured this factor. Hughes Aircraft used two methods of measuring dusting. One was to use the amount of dust collected in the bag to indicate dust generating characteristic cs. The other was by removing the dust bag and measuring the dust plume emanating from the exhaust port. See Appendix Page F-3.

The Ocean City Research tests measured dust production by dividing the increase in weight of the filter bag after the test by the weight of spent abrasive times 100 to give percent of Dust Production. See Appendix Page G-3.

Rocky Mountain Energy recorded dustiness of the test plates and test chamber surfaces for comparison between various abrasives. This was only a qualitative test.

Concerning Imbedment only two of the testers included this in their tests. Hughes Aircraft compares the color and appearance of the blasted area to a steel shot blasted plate. Any observations of discoloration or imbedded residue are recorded. See Appendix Page F-4.

Rocky Mountain Energy took microphotograph of each test plate after blasting and imbedment was evaluated from the photographs.

Profile was measured by three of the investigators. Hughes Aircraft used a profilometer. Ocean City Research used three methods for comparison. They were by Elcometer, Press-O-Film and Surfanalyzer. Rocky Mountain Energy recorded profile qualitatively from the microphotographs.

STANDARD TESTS:

There are a number of standard tests which characterize the quality and performance of abrasives. For the record these are listed below:

- Specific Gravity
- Sieve Analysis
- Moisture Content
- Loss on Ignition
- Chloride Content
- Free Flow
- Hardness
- Shape
- Free Silica
- **pH**
- Conductivity
- Oil Content
- Toxic Material?
- Radioactivity?

The last two are not yet standard tests but the U.S. Navy is in the process of developing them. Ali of the above tests are required by the Military Specification MIL-A-22262. SH.

NON-STANDARD TESTS

The following tests are those for which there are no standards and which are the subject of this investigation:

- Friability
- Dusting
- Cutting Rate
- Imbedment
- Profile

How important are these tests? A review of each of the above will show that standards are needed to evaluate each one.

Friability is the condition of being easily crumbled or pulverized. The importance of friability is threefold:

1. The more friable a material is the more energy is lost in fracturing and less in cleaning. In other words, the greater the particle breakdown, the poorer the cutting rate.

2. Friable materials generate dust which pollutes the environment and causes excessive cleanup and dust removal.

3. Friability creates poor visibility for the operator (blaster).

Dusing is limited by the regulatory bodies. The California Air Resources Board, for example, limits particle size in airborne dust to 1.8 percent maximum of 5 microns or smaller. The dust from blasting is not only from the abrasive but also from the existing paint system, rust, and sometimes fouling and other contaminants. All these factors produce dust. However, these latter sources are out of the scope of this paper. Only dust generation from abrasives is included here.

MIL-A-22262 specifies that the unused abrasive shall contain less than one percent by weight of material passing a number 70 U.S. Standard Sieve. This removes a considerable amount of fines that may be built into the abrasive before it pulverizes. 70-mesh is about 200 microns. This is one way of removing fines up front.

Cutting Rate is a measure of the productivity and efficiency of an abrasive. The speed and consumption of abrasive to produce a prescribed whiteness and profile is a major factor in the cost of blasting.

Imbedment is the result of tightly adherent particles of abrasive being forced into the metal substrate upon impact. A look through a scanning electron microscope will show that all abrasives leave residues on the surface after blasting. But without magnification some abrasives break cleanly away while others leave deposits of clay or salts or other soft materials imbedded in the surface.

In recent months failures of coatings have been attributed to contamination of the surface by the abrasive used in blasting. Is this an imbedment problem?

Profile is the roughness or anchor pattern that results from abrasive blasting. Too little profile can cause failures of some coatings because of inadequate tooth to provide proper adhesion. Too great a profile can cause pinpoint rusting due to inadequate coverage of the peaks of the profile by the coating.

There are methods of measuring profile which have been mentioned earlier. But there is no standard method per se.

For all of the above reasons there is a need for some test equipment to evaluate these factors. Hence the interest in abrasive test cabinets.

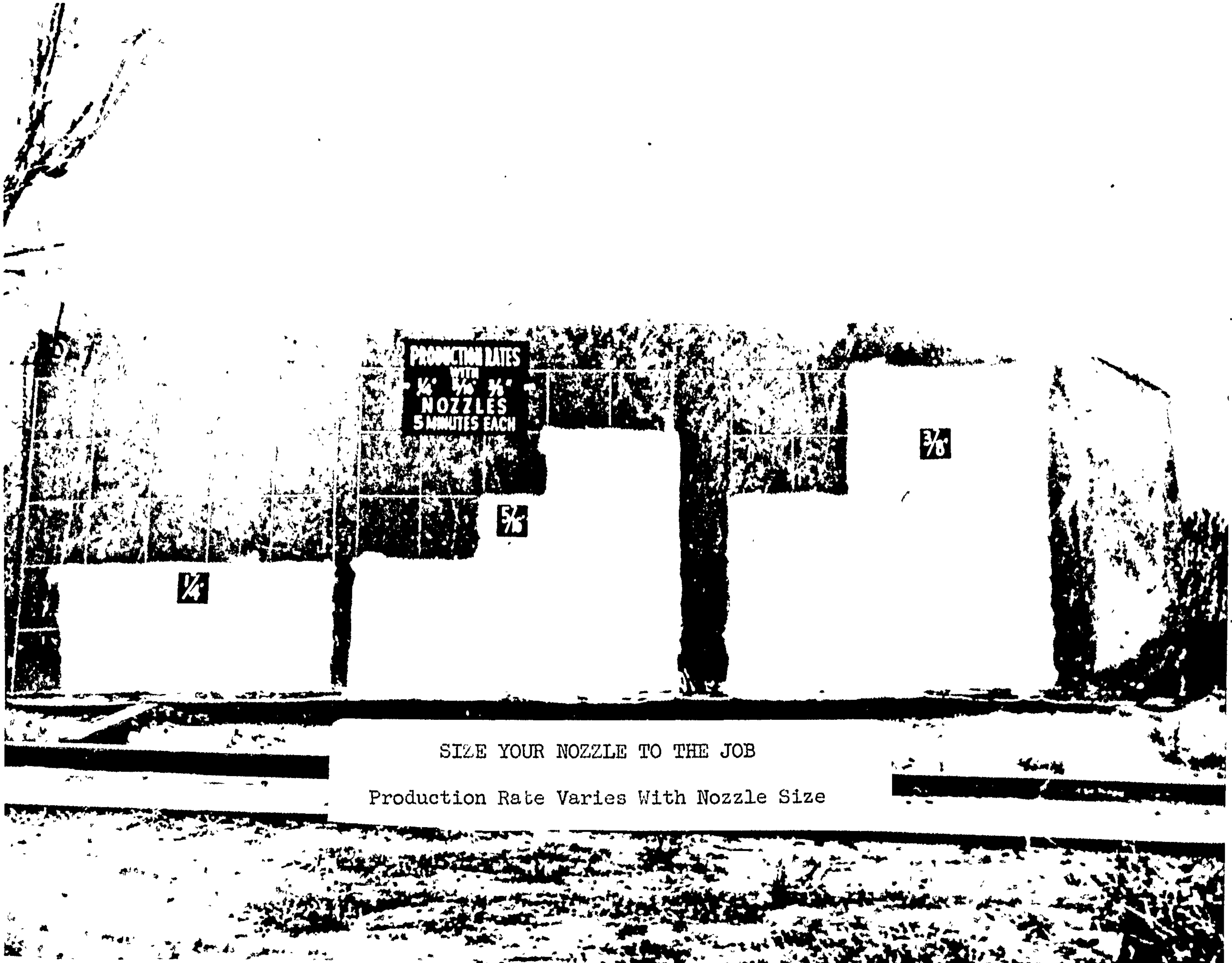
CONCLUSIONS

In reviewing the work done on these cabinets with some of the investigators, most of them will admit that if they had to do it over again, they would do it differently. Also, most said that the cabinet tests did not correlate with actual field tests. Bethlehem Steel, however, felt differently. In their opinion the cabinet gave them the results they were looking for.

There are flaws in the cabinet tests which do not simulate open blasting. These flaws must be recognized in order to understand the problem with correlating cabinet data with actual field results. For example, Figure 9 shows three steel plates blasted manually using different nozzle sizes. This is an old photograph used in CLEMCO'S training film "Blast-Off". At constant pressure and time the different size nozzles produce different cutting rates.

Done manually, the nozzles were not at 90 degrees or 45 degrees but more probably 60 degrees or some other angle. The surface blasted was about 9 sq. ft. in the slower case and 21 sq. ft. in the faster case. This relates to about four pounds of abrasive per sq. ft. In the cabinet tests the less than 1 sq. ft. test plates were blasted with 10 to 44 lbs. of grit per panel. It is clear that the surface of the small panel in the cabinet is bombarded much more heavily with abrasive than the actual field application. Further, the illustration is white metal; a near-white metal finish would be less bombarded.

FIGURE 9



SIZE YOUR NOZZLE TO THE JOB

Production Rate Varies With Nozzle Size

oto Courtesy Clemtex, Ltd., Houston, Tex.

The profile, the imbedment, and the cutting rate would not be comparable between the cabinet test and the field application. Also the friability would be different mainly because of the different angle of impingement but also because of the roughness of the plate as will be shown later.

Note that the initial condition of the steel in the illustration is S1S Grade A, i.e. with mill scale. For rusty steel or painted steel the results would be different. Another variable would be by adjusting the flow valve on the blasting pot up or down, completely different production rates could be achieved.

With regard to profile, note the example in Figure 10. This photograph is enlarged about 10 times. The abrasive used was boiler slag. Although the appearance is dark, the surface is SSPC-SP-5 white metal. Here is another example of why friability and cutting rate would be different in the test cabinet. In actual blasting, you blast a relatively smooth surface down to this roughness and then stop. But in the test cabinet you continue to bombard the roughened surface. In such case the abrasive is not cutting mill scale, rust, or paint but roughened steel. The last four pounds of abrasive and the first four pounds of abrasive would give completely different results, that is for friability, dusting, cutting rate, imbedment and profile.

Figure 11 shows that different mesh size for the same material, in this case silica sand, imparts different profiles. The purpose of this illustration is to emphasize that there are differences in performance even for the same abrasive, for different sizes within the same generic type, that are caused by the materials alone even with all factors being equal. Size is one of the variables on the list. This clearly demonstrates that variable. These graphs weremade by a Profilometer.

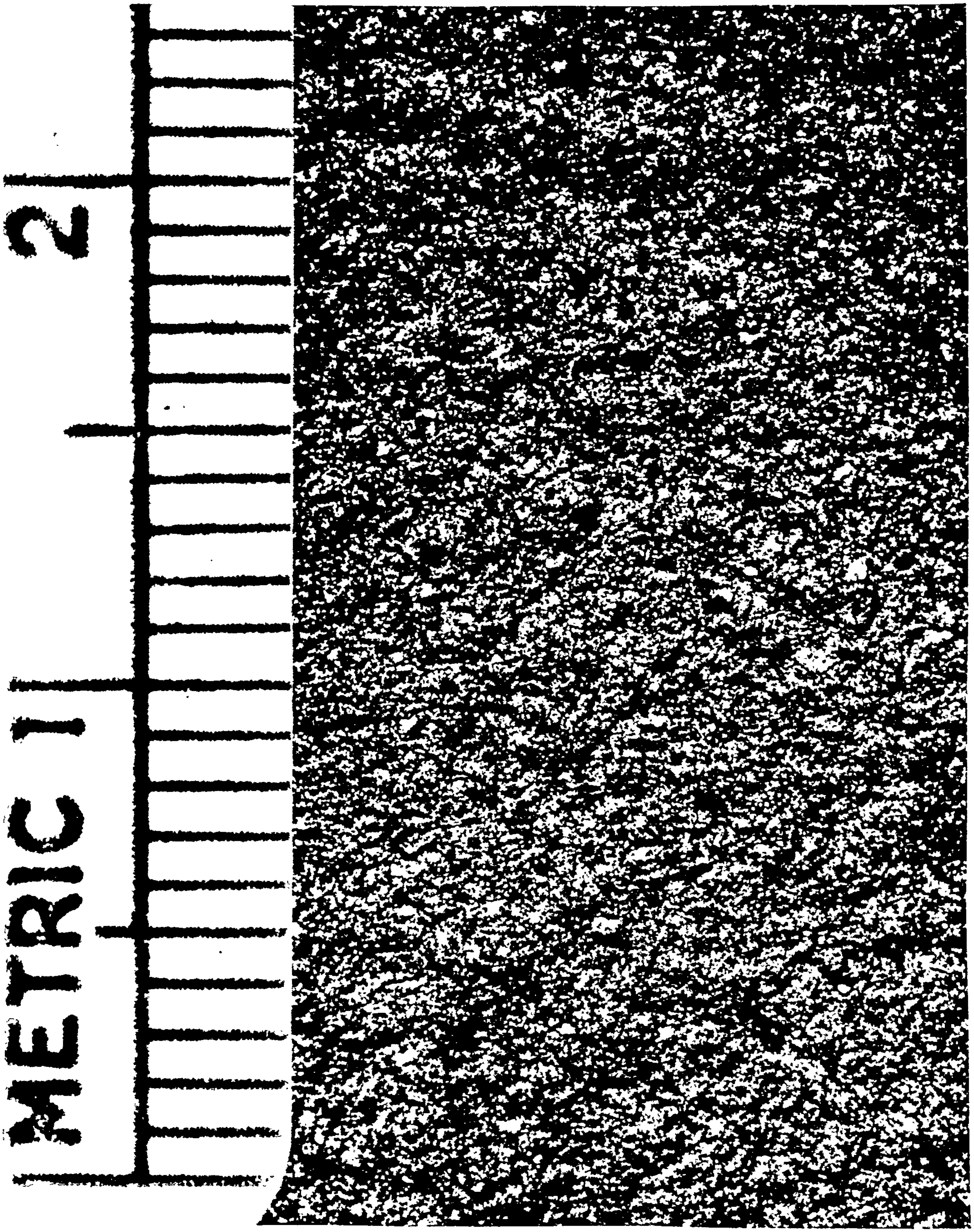
The last three figures will be recognized as nothing new. They are over 20 years old. But they illustrate principles that remain the same today for surfaces prepared by air-abrasive blasting.

Note below other items that cabinets will <u>not</u> simulate:

- Near White Metal
- Near White Profile
- Preparation of Rusty Steel
- Preparation of Painted Steel
- Preparation of Mill Scale Steel

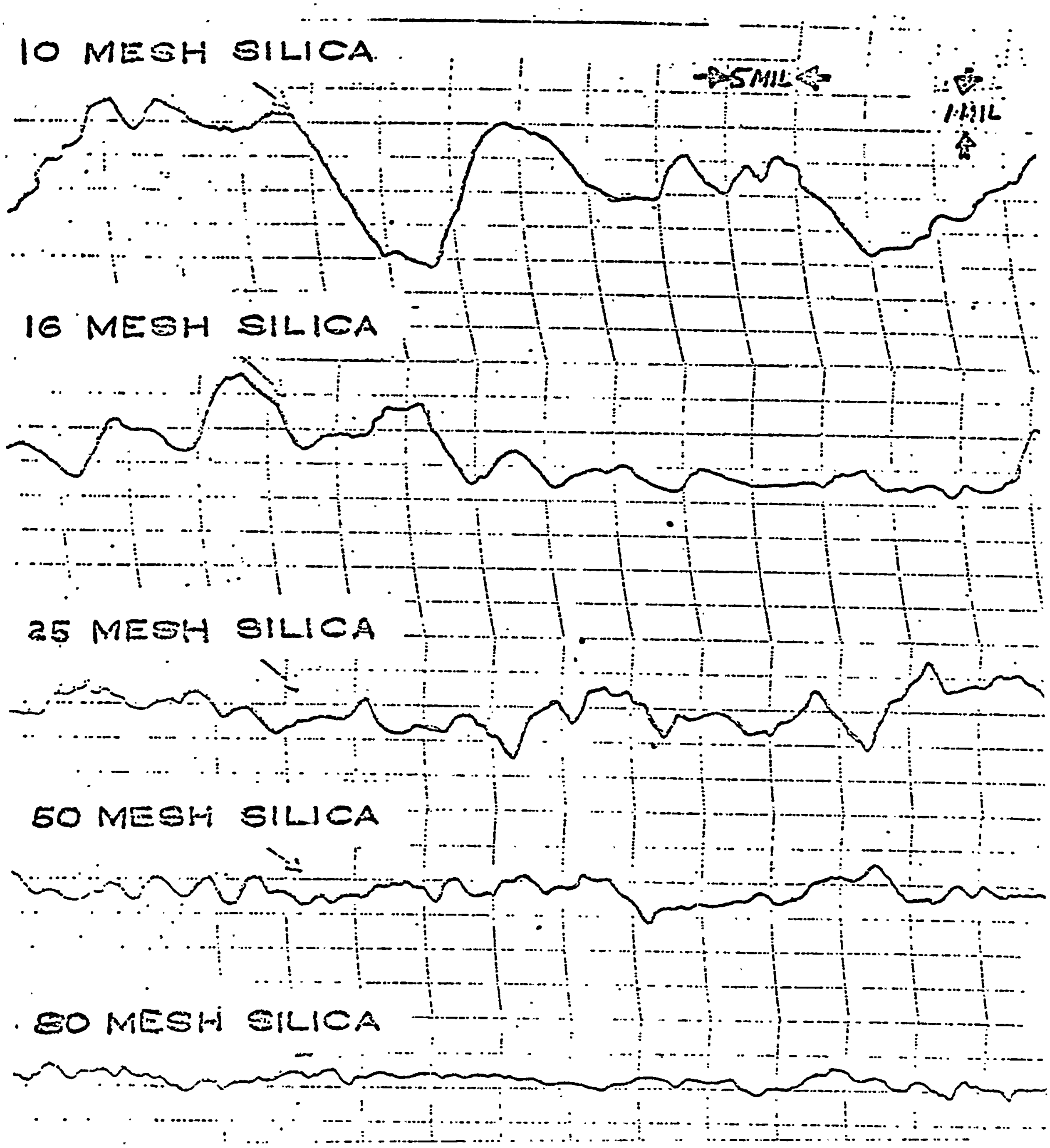
However, with further research, perhaps a cabinet could be designed using Robotics to move the blast stream across the plate or to move the plate across the blast stream to simulate manual blasting. Or perhaps a cabinet test could be used to predict results by correlating the data with open blasting and developing factors or other criteria to evaluate performance. It might also be possible to achieve a standard way of establishing rank order between various abrasives, then relate the rank order to-actual performance.

IN CONCLUSION, therefore, it is clear that none of the test cabinets reviewed in this report simulate actual field conditions. Only through further research will Such apparatus be useful as a tool for abrasive testing.



SURFACE BLASTED WITH MINERAL SLAG

FIGURE 10



PROFILES OF SURFACES BLASTED WITH DIFFERENT MESH SILICA SAND

FIGURE II

RECOMMENDATIONS

In order to pursue the matter of a standard abrasive test cabinet it is recommended that the work be conducted in three phases. Each subsequent phase would be dependent on the outcome of the previous phase.

Phase I would be as follows:

1. Appoint a Task Group of abrasive experts who include representatives from:

   - Steel Structures Painting Council
   - American Society for Testing and Materials
   - National Association of Corrosion Engineers
   - Naval Sea Systems Command
   - Society of Naval Architects and Marine Engineers, Panel 023-1
   - Abrasive Suppliers
   - Equipment Suppliers
   - Shipbuilders
   - Consultants

2. Determine which abrasives should be included in future tests. For shipbuilding limit the scope to low-silica mineral abrasives. Select three or four representative products.

3. Determine what tests are to be included in the program, i.e. friability, cutting rate, other.

4. Select three cabinets and determine if they can be made available for testing. If so, who would be the appropriate testers. For example,

   California D.O.T. - conducted by NAVSEA
   N.A.C.E. - conducted by NACE T-6G
   Rocky Mountain Energy - conducted by Contract
   Other

5. Develop test descriptions for each cabinet included in the test.

6. Poll Industry for a concensus of opinion on the proposed Phase II and Phase III. Perhaps do this through SSPC, ASTM and/or NACE.

Phase II would be to conduct cabinet tests to determine their feasibility as a standard tool for abrasive testing. The following sequence is proposed:

1. Conduct tests in three cabinets and establish a standard for all the variables discussed previously in this paper.

2. Use only the abrasives selected in Phase I.

3. Compare results to determine if there is a correlation between cabinets.

4. Determine if the cabinets are:

    - Acceptable as is
    - Need to be modified
    - Need to develop a new design

Phase III would entail field tests to develop data for correlation with the cabinet tests. The details below assume that more than just friability tests are to be included in the cabinet tests.

The following is proposed:

1. Select three locations for the tests. These could be shipyards, Navy installations, or others.

2. Design field tests for open blasting and develop test descriptions to correlate cabinet results with actual conditions.

3. Develop standards for variables for open blasting.

4. Select the medium for testing. Decide which of the following to be included. Select two.

    - SSPC - Vis 1 Grade B
    - SSPC - Vis 1 Grade C
    - Painted Steel

    Standardize each medium so that the medium can be reproduced at each test location.

5. Test each of the abrasives tested in Phase II at each location.

6. Determine cutting rate, profile, imbedment, and/or other similar to what was tested in Phase II.

7. Correlate the data from these tests with the results from Phase II.

8. If correlation is possible between Phase II and Phase III, then develop a standard cabinet test.

By copy of this report to the active task groups involved in abrasive standards and specifications throughout industry, they are invited to comment to John Peart, Program Manager, Avondale Shipyards Inc., P. O. Box 50280, New Orleans, LA 70150.

ACKNOWLEDGEMENTS

This report is the result of helpful responses by persons in the industry who contributed their time, photographs, slides, drawings, Procedures and other data. Without their cooperation and-friendly attitude this report would not be possible.

This writer is grateful to all those persons who offered their advice and provided the information contained in this report. Some of the persons who contributed are listed on the next page.

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H. Bleile	Naval Sea Systems Command	Washington, D.C.
J. Griffin	Naval Systems and Engineering Services	Philadelphia, PA
G. Gordon	Gordon Sand Co.	Compton, CA

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Table 1

COMPARISON OF TESTING CABINETS BUILT TO TEST ABRASIVE QUALITY & PERFORMANCE

DESCRIPTION	CABINET DIMENSIONS	TEST PLATE SIZE DISTANCE FROM NOZZLE	TEST PLATE MATERIAL	TEST PLATE WEIGHED	ANGLE OF IMPINGEMENT	NOZZLE SIZE	NOZZLE PSI	ABRASIVE INITIAL WEIGHT	ABRASIVE SIEVE ANALYSIS	ABRASIVE SPENT	DUSTING	CUTTING RATE	IMBEDMENT	PROFILE	OBJECTIVE
LG. BEACH NAVAL S/Y 1964	20'x 60' (PANGHORN BLDG.)	8"x4' x $\frac{1}{4}$" —	PVC PLASTIC	YES	90°	$\frac{1}{2}$"	<100	36 LBS.	BEFORE ONLY	WEIGHED	NO	TONS OF ABRASIVE PER LB. PVC CUT	NO	NO	EFFICIENCY FOR BLASTIN OF SHIP BOTTOMS
NACE 1964	1'x1'x 3' HIGH	3"x 5" x $\frac{3}{16}$" -6 INS.-	A-7 STEEL	NO	90° & 45°	$\frac{3}{16}$" STR.	90	$\frac{1}{8}$ CU. FT. (23 LBS)	30 MESH ONLY	SCREENED THRU 30 MESH	NO	DEPTH OF CUT -MILS	NO	NO	COMPARISON TESTING
DU PONT 1964	10"x 18"x 30" HIGH	8"x8"x1" -14 INS.	STEEL	NO	90°	—	95	10 LBS.	BEFORE AFTER	WEIGHED SIEVED	NO	NO	NO	NO	FRIABILITY
CALTRANS 1975	8'x 4'x 8' HIGH	10"x 10" x $\frac{3}{16}$" - 23 INS.	STEEL (ASTM A 109)	YES	90°	$\frac{3}{8}$"	100	18,750 GMS. (41 LBS)	BEFORE AFTER	WEIGHED SIEVED HYDROMETER (ASTM D-422)	NO	GRAMS LOSS	NO	NO	FRIABILITY
BETH. STEEL 1976	55 GAL DRUM	-10-12 INS.	STEEL	NO	45°	—	95	10,000 GMS. (22 LBS.)	BEFORE & AFTER	WEIGHED SIEVED	NO	NO	NO	NO	FRIABILITY
HUGHES AIRCRAFT 1978	55 GAL DRUM	12"x 13" x $\frac{1}{4}$" —	STEEL	YES	45°	$\frac{3}{8}$" VENTURI	90	20,000 GMS. (44 LBS)	BEFORE & AFTER	WEIGHED SIEVED	YES (PLUME)	WEIGHT LOSS GMS.	YES	YES	COMPARISON TESTING
OCEAN CITY RES. 1984	4'x 4" DIA (PVC)	3"x 5" x $\frac{1}{4}$" -7$\frac{1}{4}$" INS.	STEEL (SAE 1018)	YES	90°	$\frac{1}{4}$"	90	3,000 GMS. (6.5 LBS)	BEFORE & AFTER	WEIGHED SIEVED	YES	GMS. LOSS PER KG. ABRASIVE	NO	YES	CATALOG SOURCES & DEVELOP MATERIAL SPEC.
ROCKY MTN. I Y	30"x24" DIA. X 6' HIGH	6"x 6" x $\frac{1}{4}$" -7 INS.	STEEL ASTM A 36	YES	90°	$\frac{3}{8}$" VENTURI	80	5,000 GMS. (11 LBS)	BEFORE ONLY	SIEVED	YES	GMS. LOSS PER AVG. PARTICLE SIZE	YES	YES	COMPARISON TESTING

APPENDIX

-ABRASIVE TESTING CABINETS -

The attachments are additional information from the existing test cabinet investigators who contributed to this report.

W. H. Radut Associates
June 1985

PROCEDURE FOR ABRASIVE BLASTING TESTS (TYPICAL)

ABRASIVE MATERIAL Mining & Minerals
Green Diamond Checked by: C. V. Dunne

ABRASIVE CONDITION As Received (100 lb. bags) Date 6/13/63

1.	Weigh plastic sample sheet	2331 (Gr)
	Attach to back-up plate	OK
2.	Set nozzle travel 3" from top and bottorn	OK
4.	Empty blasting hose by air blast	OK
5.	Weigh and load blasting machine with sample abrasive	618#
6.	Air Pressure 100 psi	OK
7.	Vertical travel setting 17.5 Ft/Min	OK
8.	Blast 2.5 minutes (Use stop watch)	OK
9.	Remove plastic sample from back-up plate	OK
	Identify sample with abrasive	OK
11.	Weigh remaining abrasive in blasting machine	582#
12.	Weigh blasted plastic sample sheet	2290 (Gr)

SUMMARY

Weight of plastic sample before blasting	2331 (Gr)
Weight of plastic sample after blasting	2290 (Gr)
Weight of material before blast	618#
Weight of material Ieft in machine after blast	582#
Time of blast	2.5 (Min)
Vertical travel speed	17.5 (Ft/Min)
Weight of abrasive material used	36 (Lbs)
Weight of plastic material removed	41 (Gr)

REMARKS: Weigh pallet and empty 55 gal. drum. Load with measured pounds of abrasive material (net weight). Dump material into clean hopper and load blasting machine. Weigh remaining abrasive in same 55 gal. drum and pallet.

LONG BEACH NAVAL SHIPYARD

Description of CAB Testing Device*

Extensive preparations for analyzing and studying these specific properties were made. Result of these preparations was a CAB* testing device (Cabinet for Abrasive Breakdown and Abrading) in which these tests were made and can be duplicated throughout the corrosion industry: (See Figure 1.)

The abrasive breakdown and abrading testing device is a rectangular shaped metal cabinet one foot square by three feet tall with a converging lower hopper type 4-inch square outlet. The cabinet is mounted on four legs to provide adequate clearance for a container to hold spent or used abrasive being tested.

Inside the cabinet are two baffle plates in opposition to each other, mounted at 45-degree angles with the verticle to retain abrasives being blasted inside the cabinet. On the side of cabinet below the lowest baffle is an adjustable 3 by 5-inch metal coupon holder designed to provide 90 to 45-degree angles with the verticle so that abrasives will be retained inside the cabinet. On the side of cabinet below the lowest baffle is an adjustable 3 by 5-inch metal coupon holder designed to provide 90 to 45-degree angle blasting. On the opposite side of the cabinet and below the point of 45-degree angle intersection from the coupon holder is the nozzle inlet constructed to provide adjustable nozzle distance from the metal sample being blasted. The area behind the coupon holder and below the lower baffle is rubber lined to prevent secondary abrasive breakdown after initial contact with the coupon.

The work area for removing and inserting samples is available through an inspection door adjacent to the coupon holder and located in the side of the cabinet. The cabinet top is fitted with a 3-inch diameter outlet which can be connected to dust collector.

This CAB testing device is designed to be used with a pressure type abrasive blast machine. Choice of a blast machine that will allow absolute flow of all abrasive media being tested is essential. The abrasive flow to the nozzle is metered so that it is on the lean side to insure maximum breakdown.

Test Procedure

The test procedure is performed in two operations. The first. a breakdown test, and second. an abrading test.

Breakdoun Test Procedure

In this test. a sample of abrasive material being tested is screened to the following specifications: (1) zero percent retained on U.S. Sieve No. 20 and (2) 100 percent retained on U.S. Sieve No. 30.

The sample is weighed and recorded, then poured into a six-inch cubicle container (1/8 cubic foot by volume) to measure the volume. The sample is emptied into an absolutely clean pressure blast machine which is connected to a straight 3/16-inch round orifice (four inches long) boron carbide lined straight nozzle in the CAB machine. the nozzle is set perpendicular to a 3 by 4-inch by 3/16-inch thick A-7 steel panel at a distance of six inches from nozzle ourlet to panel surface.

The abrasive then is blasted at a nozzle pressure of 90 pounds per square inch measured with a needle type pressure gauge at the nozzle until all the sample is expended. An adequate capacity air transformer is necessary to maintain this nozzle pressure. Also a moisture control trap should be installed in the system. The spent sample then is rescreened on the U.S. Sieve No. 30, and the remaining sample is weighed and recorded to calculate a Percentage breakdown from the original sample

Example: Weight of Material between No. 20 by 30 Sieve

Before test	12.25 lbs.
After test	1.50 lbs.

Breakdown—

$$\frac{\text{Wgt. before test} - \text{Wgt. after test}}{\text{Wgt. before test}} = \frac{12.25\text{ lbs.} - 1.50\text{ lbs.}}{12.25\text{ lbs.}}$$

$$= 88\% \text{ of original sample}$$

CAB Hardness Number =

$$100^{*} - 88\% \text{ (Breakdown)} = 12$$

This CAB hardness of 12 represents a low hardness or toughness. Actually, the CAB hardness number is the measurement of material that does not breakdown on this test.

Abrading Test Procedure

The abrading test is conducted with a similar prescreened 20 by 30 mesh sieve sample of 1/8 cubic foot volume. The sample is blasted through the pressure blast machine as described in the breakdown test using a 3/16-inch round orifice by four-inch long boron carbide straight nozzle at a distance of six inches from the panel. The panel is at a 45-degree angle from line of abrasive blast at 90 psi nozzle pressure.

The test coupon (3/16-inch thick A-7 steel, 3 by 4 inches) is measured with a micrometer before the test in the general area of expected blast pattern. After the test, the resulting difference of micrometer measurements indicates the amount of metal removed. For example, if coupon thickness before test was 0.1875-inch and thickness after test was 0.1230-inch, then the abrading depth would be 0.0645-inch. CAB abrading number for this example would be 64.5 mils Range for this example would be 0 to 187.5 roils.

This abrading number indicates the actual depth or amount of metal removed, thus the lower the abrading number, the less productive an abrasive; the higher the abrading number, the *more* productive or the faster ability of the abrasive to remove metal.

National
Association
of
Corrosion
Engineers

† Patent Pending.

* An arbitrary range of 0 to 100 has been chosen to designate the hardness or toughness of an abrasive. A hardness number of 100 would indicate an abrasive with no breakdown.

1. Abrasive Breakdown

a. A sieve analysis is run on a representative sample containing 200 grams of the test abrasive and the data recorded.

b. The breakdown cabinet and Handi-Blaster are assembled and hooked to an air supply capable of maintaining 95 psi of air at the blast machine when the machine is in operation. A sample of the abrasive under test is run through the machine and the flow valve adjusted to give free, unchoked abrasive flow. (This is obtained when a bluish-white hue is visible when looking through the path of air and sand as it comes from the nozzle.) The equipment (both cabinet and blaster) is then cleaned so that no dust or abrasive remains.

c. Ten pounds of test abrasive are introduced into the blaster and all of it is expelled at,the predetermined settings into the cabinet. The lid of the cabinet, made up of 200-mesh screening, emoved and all the remaining abrasive and dust is brushed into the collector pan, transferred to the original. weighing container and reweighed. The loss in weight is recorded.

d. A 200(gram sample is taken from the spent sand for sieve analysis.

e. A breakdown rate is calculated from the before and after sieve analyses using the formula:

$$\text{breakdown} = \frac{\Sigma\%\ \text{spent abrasive retained X average sieve opening}}{\Sigma\%\ \text{as rec'd abrasive retained X average sieve opening}}$$

For screen sizes used, the expression becomes:

	As Rec'd	Used
.0559 x % retained on 20 mesh		
.0248 x % retained on 40 mesh		
.0131 x % retained on 60 mesh		
.0078 x % retained on 100 mesh		
.0043 x % retained on 200 mesh		
.0013 x % retained on pan & dust loss		
TOTALS		

E.I.DUPONT

The screen analysis of the spent abrasive is adjusted as follows to account for loss through the 200 mesh screen cabinet cover during blasting:

L = % loss during blasting

Spent Abrasive

Retained on	Measured, %	Adjusted, %
20 mesh	A	$A \times \frac{100-L}{100}$
40 mesh	B	$B \times \frac{100-L}{100}$
60 mesh	C	$C \times \frac{100-L}{100}$
80 mesh(if used)	D	$D \times \frac{100-L}{100}$
100 mesh	E	$E \times \frac{100-L}{100}$
200 mesh	F	$F \times \frac{100-L}{100}$
pan	G	$G \times \frac{100-L}{100}$

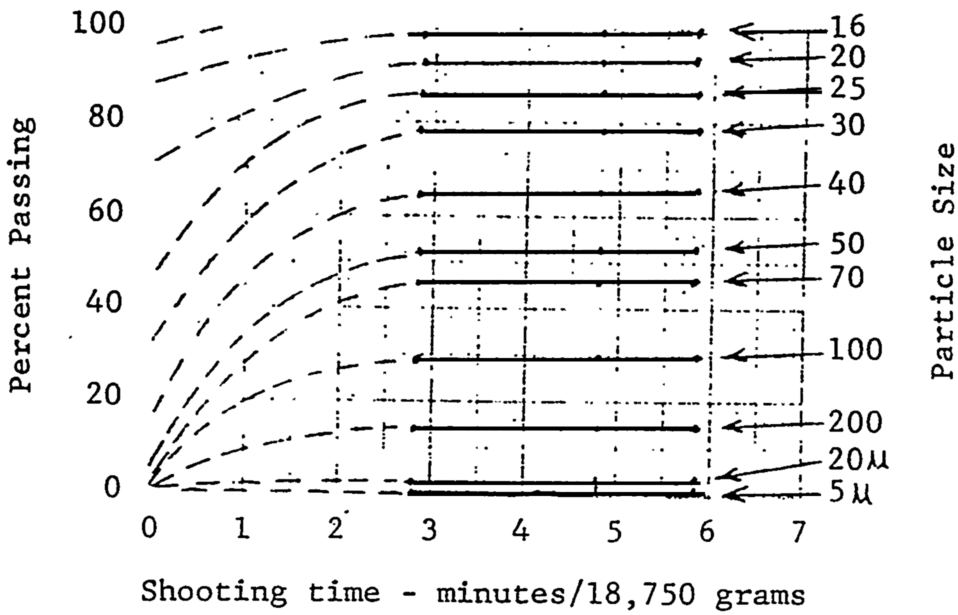

Figure 3. Gradation vs. Shooting Time

CALIFORNIA D.O.T.

So that all the abrasives might be compared at the same shooting rate, the after-blasting gradation was picked from these curves where they intersected with a shooting time of four minutes and ten seconds. This shooting time corresponds to a blasting rate of six hundred pounds of abrasive per hour for an 18,1750 gram sample.

The abrasives were grouped into eight material types using information obtained from the manufacturers. For discussion purposes a summary of the before and after blasting gradation for twenty-two typical abrasions is presented in Table 1. A complete tabulation of the before and after blasting gradation data is presented in the Appendix in Table A-1.

The grams of steel abraded from each impingement plate during the blasting was also plotted against shooting time in a manner identical to that used for the gradation. The abrasion value corresponding to a four minute and ten second shooting time is also presented in Table 1.

Table 1 - Selected Typical Abrasives -
Gradation and Abrasion Loss Results

Material	Percent Passing Before Blasting			Percent Smaller After Blasting			Grams Steel Abrasion
	#50	#70	#100	20	10	5	
Ocean Sands							
#1	0	0	0	4.1	2.0	1.0	6.2
#5	1	0	0	5.1	2.6	1.3	9.5
#6	2	0	0	7.0	3.2	1.5	9.9
#9	3	0	0	7.0	3.5	1.7	16.5
#13	8	1	0	7.7	4.0	1.9	15.7
#16	15	3	1	7.6	3.8	2.0	17.2
#18	21	4	0	8.8	5.0	2.0	17.6
#10	14	6	2	10.0	5.1	2.6	18.2
#23	60	18	2	10.6	5.3	2.6	18.2
Silica Sands							
#25	1	0	0	6.4	3.3	1.7	19.2
#24	4	2	1	7.6	5.1	3.0	15.0
#28	54	28	11	9.8	5.0	2.6	26.0
#29	80	42	13	10.8	5.6	2.6	23.1
Nickel Slags							
#34	0	0	0	2.5	1.0	0.3	28.9
#35	1	0	0	3.0	1.3	0.4	35.8
Copper Slags							
#36	1	0	0	2.5	1.1	0.3	37.0
#37	5	4	3	4.0	1.9	0.6	26.7
#38	6	4	4	3.6	2.0	1.0	27.2
Steel Slags							
#42	6	2	1	2.5	1.0	0.4	39.5
#48	0	0	0	4.6	1.8	0.5	32.1
#46	9	3	1	3.0	1.4	0.5	45.4
#45	7	1	0	4.3	3.0	2.2	41.9

ABRAS IVB BREAKDOWN TEST AND RATING FORMULA

1. Abrasive Breakdown Test Procedure

   a. A sieve analysis as outlined in ASTM D451-63 is run on a representative split sample containing approximately 200 grams of the test abrasive, and the data are recorded.

   b. The breakdown test equipment (Figure 14) is hooked to an air supply capable of maintaining 95 psig of dry air at the blast machine when the machine is in operation. A sample of the abrasive under test is run through the machine, and the flow valve is adjusted to give free, unchoked abrasive flow. (The flow is free if a bluish-white hue is visible when one looks through the path of air and abrasive as it comes from the nozzle.) The equipment (both drum and blaster) is then cleaned so that no dust or abrasive remains.

   c. Ten pounds of test abrasive having *a* sieve analysis as determined, in (a) above is introduced into the blaster, shown on right, Figure 14, and all of it is expelled at the predetermined settings into the 55 gallon drum fitted with a dust bag shown at the left in Figure 14. After blasting, the cone shaped bottom of the drum is opened, all the accumulated abrasive and dust collected and transferred to the original weighing container, and reweighed. The loss in weight is recorded.

   d. A split sample of approximately 200-grams is taken from the spent abrasive for sieve analysis.

2. Formula for Calculating Breakdown Rate

   The breakdown rate is calculated from the before and after sieve analyses, as follows:

$$\text{Breakdown rate} = \frac{\text{\% spent abrasive retained X average sieve opening}}{\text{\% as-received abrasive retained X average sieve opening}}$$

   For the following screens, the expression becomes:

	Abrasive: As-Received	Abrasive: After Breakdown
0.0559 x % retained on 20 sieve		
0.0248 x % retained on 40 sieve		
0.0124 x % retained on 70 sieve		
0.0071 x % retained on 100 sieve		
0.0043 x % retained on 200 sieve		
0.0013 x % retained on pan & dust loss		
TOTALS		

   Breakdown factors range from 1.0 for an abrasive showing no reduction from original size after blasting to approximately zero for large grains that are reduced to dust. Most quality mineral abrasives will have the rating of approximately 0.6.

BETHLEHEM STEEL

5 September 1978

ABRASIVE BREAKDOWN TEST PROCEDURE

Scope

This test is used to determine the relative degree that abrasives break down during a specific blasting operation. The relative degree of dust generation of each abrasive is also observed.

Equipment Requirements

a. Air source capable of delivering clean, dry, oil-free compressed air at 90 psig. at 300 cfm.

b. Abrasive blasting pot equivalent to a Clemco SCW-1028 or larger. The pot shall be equipped with a variable-control abrasive feed valve and shall deliver abrasive through a l/2-inch or larger hose. The air inlet shall be equipped with a moisture separator.

c. Pauli & Griffin Co. PTM6 venturi-type nczzle or equivalent.

d. Test chamber as shown on drawing SK 40523, equipped with abrasive collection cone, dust collection beg, and impingement plate holder.

e. Riffle splitter suitable for preparing 20 kg. samples.

f. Sieves - woven wire cloth sieves of Nos. 20, 30, 40, 50, 70, and 100 designations with square openings conforming to FED-STD RR-S-366.

g Sieve shaker with simultaneous rotary and tapping motion.

h. Balances or scales accurate to 0.01 percent of sample weight, with nominal capacities of 2 kg. and 20 kg.

i. Stopwatch.

j. Sample containers, nominally of l gallon size, clean, with a tight-fitting lid.

k. Impingement plates, mild steel, 12 by 13 by 1/4 inches.

l. Bag filter, 9 ounce cotton sateen, with a minimum surface area of 15 square feet.

m. Transparent polyethylene bags, approximately 10 by 18 inches and 5 by 9 inches.

HUGHES AIRCRAFT CO.

n. Photographic equipment -- camera, floodlights, and dark background paper suitable to photograph dust plumes.

o. Bendix Profilometer, Type QB model 4 with MA4-1627 head.

Procedure

a. Sample Preparation

1. Randomly taking partial samples from several places in the total abrasive lot, collect approximately 90 kg. (200 pounds) of sample abrasive.

2. Dry this material in an oven at 120° ± 5°F until a constant weight is obtained.

3. Using the riffle splitter, split the dry material into four 20,000 ± 10g. samples and four 500 ± 50g. samples.

4. Seal the eight samples in plastic bags and label them.

b. Initial Sieve Analysis

1. Perform a separate sieve analysis, in accordance with ASTM method C136-46, on each of three of the 500g. samples obtained in step a.3 above.

2. If the results of the above sieve analysis vary by more than 5 percent of the total of any one sieve, recombine and resplit the 90 kg. sample and repeat step b.l above.

c. Abrasive Blast Pot Preparation

1. Drain any water which has accumulated in the moisture separator on the air supoly inlet line.

2. Close the abrisive feed valve on the bottom of the abrasive pot.

3. Load one of the 20,000 gram samples into the pot.

4. Turn on the air and regulate it until a steady pressure of 90 psig is obtained at the nozzle. Slowly open the abrasive feed valve on the bottom of the pot until abrasive flow is just visible in the air stream. (A bluish-white hue will be visible looking through the flowpath of air and sand.) When the settings are obtained, shut off the air upstream of the air regulating valve.

5. Insert the blasting nozzle into the nozzle mount on the test chamber and secure it.

d. Dust Plume Photography

1. Install an impingement plate in the test chamber. (A used plate may be used if it is in good condition.)

2. Close up the test chamber and remove the dust collection bag from the outlet.

3. Ensure that the blasting nozzle is secure in the test chamber mount.

4. Set up photographic equipment at right angles to the dust outlet on the test chamber. Set up a dark background paper so that the dust outlet is between the background paper and the camera. Illuminate the setup with required photo floodlights.

5. Turn on the air supply to the abrasive blast pot and verify the settings. Allow abrasive impingement in the chamber to stabilize for 30 seconds before taking photographs of the dust plume exhausting from the chamber. Record the photographic parameters used.

6. Shut off the air supply at upstream valve, maintaining predetermined settings.

7. Open the test chamber, clean out all abrasives, and dust thoroughly. Remove the impingement plate and install a new impingement plate which has been weighed to 1/10 g. Close up the chamber and reinstall the dust bag.

8. Clean out all abrasives and dust from the abrasive blast pot, taking care not to disturb air or abrasive feed rate settings.

e. Abrasive Breakdown Testing

1. Introduce a premeasured (from Procedure, step a.3) abrasive sample into the clean abrasive blasting pot, being careful not to spill any of the sample.

2. Ensure that the blasting nozzle is in place on the test chamber. Open the upstream air valve on the blaster and expel the entire 20,000 gram sample at the predetermined settings into the test chamber. Record the total time required to expel 20,000 grams. Allow the abrasive pot to run 5 minutes total.

3. Empty all the spent abrasive from the drum into the plastic taking care to brush all the abrasive out of the drum and not spill any. (Note: brush-- do not blow--residual dust and abrasive from the drum.)

4. Weight the spent abrasive and record the weight loss. Bag the spent abrasive and identify it.

5. Repeat the Procedure, part d., and steps l through 4 of part e. of the Procedure until three 20,000 gram samples have been tested. The same impingement plate may be used for all three runs.

6. Remove the impingement plate, identify it, weigh it, and record the final weight.

7. Empty the dust from the dust bag into a plastic bag. Record the total weight of the dust from the three tests on the data sheet.

f. Post-Test Sieve Analysis

1. Obtain a 500 gram sample of spent abrasive from each of the 20,000 gram samples shot in the Procedure, part e.

2. Perform a separate sieve analysis on each of the three 500 gram samples in accordance with ASTM method C136-46.

3. Record the results on the abrasive breakdown data sheet and compute the breakdown index.

4. Inspect the impingement plate for dusting, imbedment and profile, comparing the plate to a new plate which has been cleaned with steel shot. Record observations on the data sheet:

   a) Dust: Wipe the blasted area with a clean white tissue and record the amount of dust picked up by the tissue as: none, slight, moderate or heavy.

   b) Imbedment: Compare the color and appearance of the blasted area to the steel shot blasted plate. Record any observations of discoloration or imbedded residue.

   c) Profile: Measure the surface roughness near the center of the blasted area and record the profile in roils (rms) on the data sheet. Use a BA follower a scale factor of 1000 and a cutoff of 0.030.

g. Precautions

1. Ensure that the air source is not pumping oil and the moisture separator is working properly.

2. Be careful not to disturb the settings of the air and abrasive feed rates during the tests.

3. Inspect the condition of the abrasive nozzle prior to each test series. If the nozzle has noticeable wear, install a new nozzle for the tests.

4. Wear ear protection while operating the test equipment.

Hughes Aircraft co. DATA SHEET

ABRASIVE BREAKDOWN TEST

MATERIAL ______________________ SOURCE ______________________

TEST DATE __________ TIME ____________ Weather Conditions __________

PERSONNEL:
Test Director ________________ Observer ____________ Blaster ______

EQUIPMENT:
Machine: Type ____________________ ID # ______________________

Nozzle: Make ____________________ Size ______________________

Hoses: Size ____________________ Length ______________________

TEST RESULTS:
TOTAL WEIGHT OF ABRASIVE USED ______________________________

TOTAL BLAST TIME ______________________________

BREAKDOWN INDEX--AVERAGE ______________________________

IMPINGEMENT PLATE CONDITIONS:

WEAR: Weight before test ______________________________

Weight after test ______________________________

Total weight loss ______________________________

DUST* ______________________________

IMBEDMENT* ______________________________

PROFILE* ______________________________

REMARKS: ______________________________

____

____

____

*Qualitative evaluation compared to steel shot blasted specimen plate

ABRASIVE BREAKDOWN DATA SHEET

MATERIAL SOURCE TEST DATE

SIEVE SIZE		ABRASIVE SIZE--AS RECEIVED						ABRASIVE SIZE AFTER BREAKDOWN					
SIEVE NO.	AVG. OPEN-ING(1)	SAMPLE #1		SAMPLE #2		SAMPLE #3		SAMPLE #1		SAMPLE #2		SAMPLE #3	
		% (3)	(4) FACTOR	%	FACTOR	%	FACTOR	%	FACTOR	%	FACTOR	%	FACTOR
20	0.0559												
30	0.02815												
40	0.0199												
50	0.0141												
70	0.0100												
100	0.0071												
pAN(2)	0.0030												
TOTAL		100		100		100		100		100		100	
BREAKDOWN INDEX(5)													
										AVERAGE			

(1) Average Opening = Sieve Opening + Previous Size Opening/2
(2) Include Weight Loss Recorded After Test
(3) % Retained on Each Sieve Size
(4) Factor = Avg. Sieve Opening X % Retained
(5) Breakdown Index = Factor Total After/Factor Total Before

NOTE: The values shown in the % column are actually the weight retained from a 300 gm. sample and are therefore exactly 3 times % retained.

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4.4.9 Blasting Tests for Cutting Rate, Breakdown Rating, Dust Production, and Surface Profile

4.4.9.1 Test Requirements - All testing shall be done using a test chamber similar to that shown in Figure B-1. A source of clean, dry, oil-free air should provide 90 psig at a 1/4" nozzle. The pressure at the nozzle should be measured with a hypodermic needle gauge. The nozzle tip shall be 7 1/4" from the steel test plate. The steel test plate shall be 3" x 5" x 1/4" (SAE 1018, hot rolled) and mounted at a 90° angle to the blast nozzle.

4.4.9.2 Test Procedure - Load the abrasive feed pot with approximately 3000 grams of abrasive. Start the compressor and regulate the pressure until 90 psig is obtained at the nozzle. Open the abrasive feed valve until the abrasive flow is just visible. Re-check the nozzle pressure. If it is still at 90 psig, shut off the air upstream of the air regulating valve. Insert and secure the nozzle into the nozzle mount. Insert a practice plate in the plate holder. While viewing from above, open the air valve and check that abrasive impingement occurs at the center of the plate. Reposition the nozzle if necessary. When the nozzle is aligned properly, shut off the air flow. Open the test chamber and thoroughly rid the chamber of all dust.

Inset a preweighed (to the nearest 0.1 gram) test plate into the specimen holder. Preweigh the filter bag and the abrasive catch bucket to the nearest 0.1 gram. Fill the abrasive feed pot with approximately 3,000 grams of sample. Turn on the air flow and blast the plate until at least 1,000 grams of abrasive have been consumed. When the blasting is complete, remove and weigh the filter bag. Record this value. Open the chamber top to brush the dust from the baffles and walls into the abrasive catch bucket. Remove the bucket and weigh it. Record this value. Record the post-blast weight of the test plate.

4.4.9.3 Post-Blast Data Reduction

4.4.9.3.1 Cutting Rate - The cutting rate is defined as the grams of metal lost from the test plate per kilogram of spent abrasive. It is computed as follows:

$$\text{cutting rate} = \frac{\text{plate weight loss (gms)}}{\text{spent abrasive (gms)}} \times 1000$$

where,

plate weight loss, gms = (pre-blast plate weight) - (post-blast plate weight)

spent abrasive, gms = (post-blast weight of filter bag + abrasive catch bucket weight) - (pre-blast weight of filter bag + abrasive catch bucket weight)

4.4.9.3.2 Breakdown Rating - The spent abrasive in the catch. bucket shall be split into a 200-250 gram representative sample in accordance with ASTM C702-80 Method A. The sample shall then be sieved in accordance with ASTM D451-80. As in 4.6.8. the pans shall be Nos. 10, 20, 30, 40, 50, 60, 70, 100 and a catch pan. Record the percent abrasive retained on each screen. Only one sample shall be sieved after testing. The breakdown rating shall be calculated as illustrated in the example below. (It is necessary to use the pre-blast sieve analysis performed in 4.6.8)

Example

Sieve No.	Average Opening	Pre-Blast Sieve Analysis %	Pre-Blast Sieve Analysis Factor	Post-Blast Sieve Analysis %	Post-Blast Sieve Analysis Factor
10	0.08583	15.37	1.3192		
20	0.05610	60.52	3.3952	21.79	1.2224
30	0.02854	14.29	0.4078	17.51	0.4997
40	0.02018	5.54	0.1118	16.46	0.3322
50	0.01427	1.81	0.0258	15.16	0.2163
60	0.01083	0.11	0.0012	5.80	0.0628
70	0.00909	0.45	0.0041	5.33	0.0484
100	0.00713	0.11	0.0008	6.90	0.0492
Pan	0.00295	0.23	0.0007	11.61	0.0342
			Sum = 5.2666		Sum = 2.4653

where,

% = Weight percent abrasive retained on each screen
Factor = % x Average opening

$$\text{Average opening* (in inches)} = \frac{\text{(Sieve Opening + Previous Size Opening)}}{2 \text{ X } 25.4}$$

thus,

Breakdown Rating = 2.4653/5.2666 = 0.47

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*As examples,

For No. 10 = (No. 10 + No. 8)/2 = (2.00 mm + 2.36 mm)/2x25.4
= 0.08583

For No. 20 = (No. 10 + No. 20)/2 = (2.00 mm + 0.850 mm)/2x25.4
= 0.05610

4.4.9.3.3 Dust Production - The percent dust production is defined by the following formula:

$$\% \text{ Dust Production} = \frac{\text{(post-blast wt. of filter bag - pre-blast wt.)}}{\text{spent abrasive}} \times 100$$

where, spent abrasive is as defined in 4.6.9.3.1.

4.4.9.3.4 Surface Profile - The surface profile shall be measured at the center of the test plate using Press-O-Film*. The coarse grade shall be used for profiles of O-2 roils and the x-coarse grade for profiles of 1.5-4.0 roils. The manufacturer's directions shall be followed in using the film.

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* Available from Testex Inc., P.O. Box 867, Newark Delaware, 19711

PILOT-SCALE TEST PROCEDURE AND COMMENTS

Steel Plates

1. Samples of abrasives were procured from commercial suppliers in 100 lb bags. Typically, a pallet quantity of 20-30 bags of abrasives was bought so that enough sample was available for screen analysis as received, chemical analysis, and both pilot-scale and full-scale testing of uniform, representative lots of product.

2. Upon receipt of materials, random bags were selected and were split by riffle splitters into approximately 200 gram samples. Screen analysis using US sieves #8, #12, #16, #20, #30, #40, #70, #1OO. and #200 was determined. These were chosen partially because they were in use in our production quality control lab and available. but the #70 was used to check compliance with regulatory limits of less than 1% passing for the California Air Resource Board. The #200 sieve gave an initial measurement of dustiness. ASTM procedure C136 was used. including a Rotap shaker to produce consistent results.

3. The pilot-scale test unit was set up as shown on Figure 10 and connected to a 375 CFM portable air compressor capable of supplying 120 psig air (measured at the compressor). A 3/8″ Venturi nozzle and a 1“ diameter sand control valve were assembled with a 1“ pressure regulator and pressure gauge.

4. A 50-foot 2" diameter hose was connected to the air compressor and coupled to the quick disconnect fitting with wire through the fittings to protect personnel from injury

in case of failure of the fitting or inadvertent disconnection while pressurized.

5. A moisture separator was installed at the test unit rather than the preferred location at the compressor discharge because appropriate fittings were not available to hook it up at the compressor.

6. A 6“x6"xl/4” ASTM A36 steel plate was weighed on a lab Mettler balance and clamped tightly in place, and the nozzle assembly moved to provide a 7“ clearance from nozzle tip to the plate surface to be blasted.

7. All fittings were checked and valves closed for start-up. The compressor was started and run for 15 minutes to get the compressor to operating temperatures. Cracking the moisture separator slightly allowed condensate to escape.

8. Air pressure at the compressor was adjusted to 120 psig and periodically checked.

9. The valve to the nozzle was opened and pressure adjusted at the local regulator to 80-82 psig under no material flow conditions with the sand control valve wide open.

10. Once preliminary adjustments were made, a test. sample of 5000 grams was weighed out on a platform scale to 0.01% accuracy ±5 grams) and transferred into the abrasive chamber with the local air shutoff valve closed. Air was introduced by rapidly opening the shutoff valve and starting a stopwatch simultaneously. After steady state

was achieved, usually within 10-15 seconds, the pressure regulator was adjusted to 80-82 psig under full load conditions. This was checked frequently over the course of testing. but never varied enough to cause an adjustment to reset.

11. When the abrasive had passed through the nozzle a definite volume change in sound occurred each time. This was selected as the indication of completion and the stopwatch was stopped. The air shutoff valve was closed, pressure within the test chamber allowed to dissipate, and the access door opened to inspect and remove the plate. The test plate was weighed and data (time. weight. observations) recorded.

12. The test plate was turned over and the test steps 10 and 11 repeated. Both times were compared to check repeatability of results.

13. The test procedure steps 10-12 were repeated for each product available. Additionally, the bulk density of each product was tested. A bucket of about 1/4 cubic foot was filled with water, weighed, and temperature measured. Volume was calculated from the known density and weight of water. Loose bulk densities were measured by pouring the products into the bucket, striking the bucket full with a rod, and weighing the bucket. Weight was divided by volume to get a loose bulk density measured in lbs/ft^3. This data was added to the tabulation of test data.

14. Observations about dustiness of the test plates and test chamber surfaces along with any other noted occurrences were recorded for later review.

15. The test plates were marked with an indelible marker and inspected immediately before corrosion began. which in our location was noticeable in 1-2 days. Microphotograph were made under controlled conditions for reference and further analysis of embedment and profile. These proved to be invaluable to our understanding of results.

16. Selected tests were rerun to confirm repeatability and to collect spent abrasive samples for sieve analysis to look at breakdown indexes.

PVC Plates

1. All conditions were held identical to those for steel except for the following:

a. PVC plates were thicker, so the nozzle was moved 1/4″ back to maintain a 7“ clearance.

b. Test changes were reduced to 1600 grams to compensate for the expected deeper cutting of PVC in addition to increasing the thickness of PVC to 1/2″.

2. Steps 10-15 were repeated for the PVC test series on all products.